THESIS

The Profits from the
Use of Fertilizers

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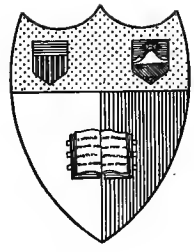

THE PROFITS FROM THE USE OF FERTILIZERS.

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Submitted to the Faculty

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by

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C O N T E N T S.

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Introduction.

The use of commercial fertilizers has increased at the rate of about ten per cent annually for a number of years; and the farmers of the United States now spend more than $100,000,000.00 for these materials every year. This indicates that some farmers, at least, think that it pays to use chemical manures.

There is no doubt that on certain soils and with some crops fertilizer does pay. But it is also true that its use is not profitable on all soils and all crops. We must recognize the individuality of the soil as of great importance and as a factor that must not be lost sight of. While it is true that some soils will respond more readily to certain fertilizers than others, it may also be true that the individuality of the plant and its food requirements are as well marked as those of soil.

In preparing the material for this paper I have taken results from some of the oldest and

most reliable fertilizer experiments in this country. I have endeavored to find out, as far as possible, if certain of the major crops respond more readily to fertilizers than others, and also what combination, or combinations, of fertilizers more generally give good results.

II.

Method Used.

To determine if a fertilizer is profitable it is necessary that we know the cost of the materials used and the value of the increased crop. But this is not all, for weshould know the cost of hauling and of applying these materials, and of still more importance, perhaps, the cost of harvesting the increased crop. Practically all experiments stations give as profits the value of the increase less the cost of the fertilizer, yet it is easy to see that if a larger crop is grown it will cost more to harvest it. For example we pay as much per pound for harvesting cotton and it is the same whether the yield is two hundred or two thousand pounds per acre. Suppose we apply acid phosphate costing $2.00 and get an increased yield of 200 pounds, which at 4½¢ per pound amounts to $9.00.

It cost one-half a cent a pound to harvest this cotton, or $1.00, therefore the gain is not $7.00, but $6.00 per acre. Should we apply a complete fertilizer costing $6.00 and get a gain of 300 pounds, the value would be $13.50 substracting the cost of fertilizer we have $7.50, which is greater than that for phosporic acid, but when we substract the cost of harvest we have $6.00 which is the same value above cost of fertilizer and cost of harvest as that produced by phosphoric acid alone. This means that the farmer would receive the same amount above the cost of fertilizer and harvest for an expenditure of $2.00 that he does for an expenditure of $6.00. In a case of this kind, it looks reasonable to suppose that the farmer should put the small amount of money which he has to invest in fertilizers where it will count for most, and would therefore purchase only phosphoric acid in case the results were similar to the arbitrary example above.

It is also easy to see that if the price of the crop decreased to say .036 per pound, (other factors remaining constant) the net gain above the cost would be much in favor of the phosphoric acid. Similarly, if the price of the crop increases say to .054 per pound, we will have a greater net gain

from the use of the complete fertilizer, amounting to ninety cents more than that of phosphoric acid. But even here there is an extra expenditure of $4.00 to obtain only ninety cents above the expenditure of $3.00 for phosphoric acid alone; and it is exceedingly doubtful if many farmers can afford to use this extra money to so small advantage. They certainly could not if a part of the crop were wholly without fertilizer. Furthermore, an increase in phosphoric acid might be better than to add other elements. This is one thing we would like to know.

The cost of fertilizers varies depending upon the distance from the seaboard, the amount purchased in the community and the form in which it is bought. In bulletin 160 of the Vt. Experiment Station, we have given the average seaboard price for a number of years for nitrogen, potash and phosphoric acid, and also the average price paid by the farmers of that state for these materials as mixed fertilizer. We have used approximately these figures as one extremes for the cost of fertilizers together with an intermediate cost which we believe will represent fairly well the price paid by the farmer who buys his raw material in comparatively large amounts.

It is practically certain that they will not get it at seaboard prices.

The price of the crop also varies with the locality as well as from year to year. We have therefore taken the average farn price for ten years on December 1st, for corn, wheat, oats and hay, (as given in the 1910 year book for the North Atlantic, South Atlantic and North Central States East of the Miss. River). This approximately represents the middle selling price with the extremes about twenty per cent above and below this figure. The price of straw, stover and cotton have been estimated as no exact figures could be obtained.

In calculating the results I have taken the average increased yields for a number of years as given by the various stations. The fertilizer combinations considered are, Phosphoric Acid, Nitrogen and Potash, used separately and in the following combinations: Nitrogen and phosphoric Acid; Nitrogen and Potash; Phosphoric Acid and Potash, and Nitrogen, Phosphoric Acid and Potash. The value of the increased yield has been determined according to the three arbitrary sale standards. The cost of

the fertilizer has been determined in like manner and an estimated cost of harvest has been made. In the absence of the facts, we have itemized a part of the extra expense of some of the crops, which we believe will come near the average on a good farm. In doing this only the grain has been considered for the cereals, but could we make allowance for the straw or stover it would not affect the results appreciably.

Extimated cost of harvest per bushel of wheat:---

Twine	.015	per bu.
Help and teams for hauling from field.	.05	" "
Board for help and thrashers	.01	" "
Help at threshing machine	.02	" "
Pay to threshers,	.03	" "
Total Cost	$.125	" "
Oats for same items	.075	
Corn,- husking, cribbing extra work with stover	.10	
Cotton	.05	per Lb.
Hay	1.00	" Ton

It will be seen that I have not made any extra charge for increased draft in cutting corn, oats, wheat or hay. These figures may seem high to some and low to others, but the various items will differ in different sections. For instance, in the South Atlantic states for wheat in would cost from 4.5¢ to 8.0¢ per bushel to pay the threshers but the help and the teams to draw the grain from the field would undoubtedly cost less than 5¢ per bushel.

I have included these cost items not so much because of their accuracy as for the fact that they are as much a part of the expense as is the original cost of the fertilizer. Of course, there are other cost items not mentioned such as hauling the fertilizers to the farm, mixing, applying and so on, but with the range in cost of fertilizer and selling price I have given, it would be comparatively easy for any one to pick out a combination in the tables to include these.

In the tables which follow I have figured that for every increased bushel of wheat it cost 13.5¢ to get it threshed and into the barn. The sale prices used for the wheat are 72¢, 90¢

and $1.08 per bushel. The same results would have been obtained had I valued the grain at 59½¢, 77½¢ and 95½¢ per bushel and said nothing about the cost of harvest. But I have included it in this work in order that the importance of it may be more clearly seen. If the cost of harvest is less it means that the sale price of the grain should be less to give the same results. On the other hand, if the cost of harvest is more it means that the sale price must be increased in order to give the same results. This will hold for all the crops.

It will be noticed that the same valuation on the fertilizing elements is given whether they are used singly or in combination. This may be justifiable since the cost of applying would be less for a combined application of the three fertilizing constituents than to apply them separately. If we buy them separately we must mix them. In most cases where a complete fertilizer is used it is bought already mixed, and if so a good price is paid for the mixing and the elements cost more than if bought separately.

III.

Results of the Investigations.

Before taking up the results of the experiments, let it be understood that it is not my purpose to critisize the works of the different experimenters, but rather to take the results as published and try to see under what conditions it would pay the farmer to use fertilizer and what fertilizer he should use, assuming that the soil and the climatic conditions were such as to approximate the results shown in the experiments. The conclusions reached will not be influenced by those of the original investigators, and hence may or may not coincide with theirs. The studies in this paper are limited to the effects of nitrogen, phosphoric acid and potash, applied separately and in combination, on increased yield, value, value over cost of fertilizer and cost of harvest, and percentage of increase on fertilizer investment.

The following outline shows the fertilizer combinations which are used in this paper:

1. Nitrogen applied alone.
2. Phosphoric acid applied alone.
3. Potash applied alone.

4. Nitrogen and Phosphoric acid in combination.

5. Nitrogen and potash in combination.

6. Phosphoric acid and potash in combination.

7. Nitrogen, phosphoric acid and potash in combination.

1.

Results at Wooster, Ohio.

In this experiment a five year rotation was followed in which corn, oats, wheat, clover and timothy were grown. The cereals were all fertilized while the hay received no fertilizer. Any increase in the yield of hay may be taken as a result of the residual effect of the fertilizer. The results are for an average of seventeen years and are published in Circular 114 of the Ohio Agricultural Experiment Station.

A. Corn.

Table 1 shows the increased yield per acre of grain and straw due to fertilizer treatment. The value of this increase is also given, with three different prices for grain and stover. All fertilizer treatments increased the yield and hence the

Table 1. Fertilizers on Corn grown in five years rotation at Wooster, Ohio. Average increase per A. for seventeen years. Value of increase.

Lbs. per A.			Inc. in bu. per A.	Inc. in Lbs. st. per A.	Value of grain	Value of stover	Total Value of increase
N	P_2O_5	K_2O					
When Corn brings 47¢ per Bu., Stover $4.00 per ton							
25-1/3			4.67	180	2.20	.36	2.56
	11.2		7.36	195	3.46	.39	3.85
		40	4.25	268	3.00	.54	3.54
25-1/3	11.2		13.76	342	6.47	.68	7.15
25-1/3		40	6.28	333	2.95	.67	3.62
	11.2	40	13.27	545	6.24	1.09	7.33
25-1/3	11.2	40	17.49	674	8.22	1.35	9.57
When Corn brings 59¢ per bu., Stover $5.00 per ton							
25-1/3			4.67	180	2.76	.45	3.21
	11.2		7.36	195	4.34	.49	4.83
		40	4.25	268	2.51	.67	3.18
25-1/3	11.2		13.76	342	8.12	.85	8.97
25-1/3		40	6.28	333	3.70	.83	4.53
	11.2	40	13.27	545	7.83	1.36	9.19
25-1/3	11.2	40	17.49	674	10.32	1.68	12.00
When Corn brings 71¢ per bu., Stover $6.00 per ton							
25-1/3			4.67	180	3.32	.54	3.86
	11.2		7.36	195	5.23	.58	5.81
		40	4.25	268	3.02	.80	3.82
25-1/3	11.2		13.76	342	9.76	1.03	10.79
25-1/3		40	6.28	333	4.46	1.00	5.46
	11.2	40	13.27	545	9.42	1.63	11.05
25-1/3	11.2	40	17.49	674	12.42	2.22	14.64

value of the crop. The order of increase in value was-----

N P K, P K, N P, P, N K, N and K.

If we consider this table alone we would say that a complete fertilizer should be used, but Table 3 leads us to a different conclusion. Take the column marked gain over cost of fertilizer and harvest, and in every case we find a loss from the use of N applied singly and also from N and Potash in combination without phosphorus. The greatest gains over cost came from the use of phosphorus and potasium combined. The single application of phosphoric acid, in general, gave the second largest gain. If, however, we take the highest prices for crop and lowest costs for fertilizer, the complete fertilizer gave a greater gain than phosphoric acid alone. We also note that if the value of the crop is low and cost of fertilizer high there is an actual loss from the use of complete fertilizer.. Single applications of phosphoric acid under all circumstances gave the greatest per cent increase over the fertilizer investment. Phosphoric acid and potash in combination was next best in this respect.

With these conditions the conclusion is:

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Apply phosphoric acid to corn, and perhaps a smaller application of potash than was used in this experiment. The potash becomes more and more justifiable as the cost of fertilizer decreases, or as the value of the crop increases. I do not see that it is a paying proposition to apply nitrogen to corn under these circumstances either alone or in combination.

b. Oats: As with corn I find the greatest increase from a complete fertilizer containing N P K, (see table 3) This was followed by N P, P K, P, N K, and N in the order given. In table 4, we see that N and N K did not pay the cost in either case. Only in one instance did the single application of potash show a gain, which was only 15¢. Where phosphoric acid alone was applied there was the largest money return over cost of fertilizer and cost of harvest. The only exception was where we figured the maximum price of crop and minimum cost of fertilizer. Here there seems to be a slight difference in favor of the combinations of phosphoric with nitrogen and potash. In case of N P the gain over P alone was 3¢ for an expenditure of $4.05.

Table 3. Fertilizers on Oats grown in five years rotation at Wooster, Ohio. Average increase per A. for seventeen years and value of increase.

Lbs. per A.			Inc. Bu-Pr. A.	Inc. Lbs. Straw Per-A.	Value of Inc. Grain	Value of Inc. Straw	Total Value of Increase.
N	P_2O_5	K_2O					
When Oats bring 36¢ per Bu. and Straw $4. per Ton.							
25-1/3			3.99	148	$1.44	$ .30	$ 1.74
	11.2		8.40	357	3.02	.71	3.73
		40	3.45	118	1.24	.24	1.48
25-1/3	11.2		15.07	683	5.42	1.37	6.79
25-1/3		40	5.90	380	2.12	.76	2.88
	11.2	40	11.72	576	4.22	1.15	5.37
25-1/3	11.2	40	18.10	932	6.52	1.86	8.38
When Oats bring 45¢ and Straw $5.00 per Ton.							
25-1/3			3.99	148	1.80	.37	2.17
	11.2		8.40	357	3.78	.89	4.67
		40	3.45	118	1.55	.30	1.85
25-1/3	11.2		15.07	683	6.78	1.71	8.49
25-1/3		40	5.90	380	2.65	.95	3.60
	11.2	40	11.72	576	5.27	1.44	6.71
25-1/3	11.2	40	18.10	932	8.14	2.33	10.47
When Oats bring 54¢ per bu. and Straw $6. per Ton.							
25-1/3			3.99	148	2.15	.44	2.59
	11.2		8.40	357	4.54	1.07	5.61
		40	3.45	118	1.86	.35	2.21
25-1/3	11.2		15.07	683	8.14	2.05	10.19
25-1/3		40	5.90	380	3.19	1.14	4.33
	11.2	40	11.72	576	6.33	1.73	8.06
25-1/3	11.2	40	18.10	932	9.78	2.80	12.58

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P K gave an increase of 50¢ for an ex enditure of $1.80. N P K gave an increase of 39¢ for an expenditure of $5.85. As to per cent gain on fertilizer investment, phosphoric acid ranks first and P K combination second.

Under these conditions the single application of phosphoric acid pays best and is the only fertilizer which would be recommended for oats. I would advise an increase in phosphoric acid rather than the addition of any other element.

c. Wheat: (Table 5) The increased values of wheat follow the same principal as the oats, that is, a complete fertilizer stands first followed by N P, P K , P, N K, N and K. I notice, however, that the increased values from all applications containing P are greater than with oats ~~than with~~ of corn, but this, no doubt, was due to the fact that the phosphoric acid application was doubled that for corn or oats.

Table 6 shows the net gain over cost of fertilizer and of harvest to be greatest, in four cases out of nine for the single application of phosphoric acid. In five cases the complete fertilizer gave the greater gain over cost than did phos-

Table 5. Fertilizers on Wheat grown in five year rotation at Wooster, Ohio. Average increase per A. for seventeen years. Value of increase

Lbs. per A			Inc. Bu. per A.	Inc. Lbs. Straw per A	Value of Inc. Grain	Value of Inc. Straw	Total Value of Inc.
N	P_2O_5	K_2O					
When Wheat sells for 72¢ per Bu., Straw $3. per ton							
25-1/3			2.07	331	$1.49	$ .50	$ 1.99
	22.4		8.03	749	5.78	1.13	6.90
		50	1.35	178	.97	.27	1.24
25-1/3	22.4		13.43	1389	9.67	2.08	11.75
25-1/3		50	2.78	369	2.90	.55	3.55
	22.4	50	9.07	782	6.53	1.17	7.70
25-1/3	22.4	50	16.29	1800	11.73	2.70	14.43
When Wheat sells for 90¢ per Bu., Straw $3.75 per ton							
25-1/3			2.07	331	1.86	.62	2.48
	22.4		8.03	749	7.23	1.40	8.63
		50	1.35	178	1.22	.33	1.55
25-1/3	22.4		13.43	1389	12.09	2.60	14.69
25-1/3		50	2.78	369	2.50	.69	3.19
	22.4	50	9.07	782	8.16	1.47	9.63
25-1/3	22.4	50	16.29	1800	14.66	3.37	18.03
When Wheat sells for $1.80 per Bu., Straw $4.50 per ton							
25-1/3			2.07	331	3.24	.74	3.98
	22.4		8.03	749	8.68	1.68	10.36
		50	1.35	178	1.46	.40	1.86
25-1/3	22.4		13.43	1389	14.50	3.13	17.63
25-1/3		50	2.78	369	3.00	.83	3.83
	22.4	50	9.07	782	9.80	1.76	11.56
25-1/3	22.4	50	16.29	1800	17.60	4.05	21.65

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phoric acid. This occurred with the relatively high values for the crop. In four instances nitrogen and phosphorus in combination gave slightly larger gain over cost than did phosphoric acid alone. If we consider the mean value of the crop and the mean cost of fertilizer, there is hardly any difference in value over cost between applications of P, N P, or N K P. The percent on investment is much greater in all cases from the use of phosphoric acid alone. Few farmers could afford to apply anything more than phosphoric acid. If, however, the price of grain was good and fertilizer could be had at a reasonable price, small applications of nitrogen and potash might be combined with phosphoric acid to good advantage, say, five pounds of each per acre.

d. Hay: Table 7 gives the increased yield of hay which occurred in two years due to the residual effect of the fertilizer. In every case the increase of clover hay was greater than the timothy except where nitrogen was applied singly I have taken the value of clover and timothy at the same figure, but if this were not justifiable the proportion of the timothy to the total increase is close enough in all treatments to off-set any great error

Table 7. Residual effect of fertilizers on Hay, (clover and timothy) grown in five year rotation at Wooster, Ohio. Average for seventeen years.

Fert. Appld to corn, oats and wheat.	Increased Yields: Lbs. Clover	Timothy	Total	Inc.	Value of Harv. @ $1. prT	Cost of Harv.	Val. of inc. over cost of Har.
	When Hay is worth $9.74 per Ton.						
N	355	433	788	3.84	.39		3.45
P	536	272	808	3.94	.40		3.54
K	291	135	426	2.07	.21		1.86
NP	1153	811	1964	9.56	.98		8.58
NK	434	366	800	3.90	.40		3.50
PK	996	489	1485	7.23	.74		6.49
NPK	1446	1031	2477	12.06	1.24		10.82
	When Hay is worth $12.18 per Ton.						
N	355	433	788	4.80	.39		4.41
P	536	272	808	4.92	.40		4.52
K	291	135	426	2.59	.21		2.38
NP	1153	811	1964	11.96	.98		10.98
NK	434	366	800	4.87	.40		4.47
PK	996	489	1485	9.04	.74		8.30
NPK	1446	1031	2477	15.08	1.24		13.84
	When Hay is worth $14.62 per Ton.						
N	355	433	788	5.76	.39		5.37
P	536	272	808	5.91	.40		5.51
K	291	135	426	3.11	.21		2.90
NP	1153	811	1964	14.36	.98		13.38
NK	434	366	800	5.85	.40		5.45
PK	996	489	1485	10.85	.74		10.11
NPK	1446	1031	2477	18.11	1.24		16.87

arising from this.

The value of the increase due to the residual effect of fertilizer is not far from the effect of the direct application to corn, generally slightly greater than the increased value of oats and less than the increased value of wheat. Nitrogen applied singly, however, gave a greater increase on the hay than the direct effect on either of the cereals. This was most marked in timothy, indicating that nitrogen may possibly be applied to timothy with profit. The residual effect of nitrogen on the hay was almost equal to that of phosphoric acid.

e. Results of the Complete Rotation:

Table eight shows the total fertilizer materials and their cost, total cost of harvest, total value of increase over cost and the per cent gain on the fertilizer investment for one rotation of five years. The results are the average of seventeen years and were obtained by summing up the results of the individual crops.

The total value of the increase was greatest for N P K the other fertilizers following in this order--- N P, P K, P, N K, N and K, thus showing that phosphorus was the most important single element.

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The value of the increase over cost of production shows some interestimg figures. As in all cases this value increases with the increase in the price of the crop and decreases with the increase of cost of fertilizer.

Single applications of nitrogen were able to pay the cost only where we figured the minimum cost of fertilizer and the maximum value of crop. N K shows a loss in all cases. K applied alone shows a loss in three cases out of nine. All other treatments show some gain over cost. The treatment showing the greatest net gain over cost of fertilizer and cost of harvest was N P K in seven cases out of nine. The greatest gain was $40.32 and the smallest $7.60. Phosphoric acid applied singly shows the greatest gain over cost than any other treatment where the prices of the crops are low and the cost of fertilizers relatively high. The greatest gain from phosphoric acid as figured is $22.91 and the smallest $12.62. This again shows that the price of the crop and fertilizer are not as important in the case of phosphoric acid as in the case of complete fertilizers, or fertilizer containing N. The greatest

net gain as figured from complete fertilizer is $40.32 or $17.41 more than that of P2 O5. Extra expenditure was $18.26. Or putting it differently for $2.01 paid for P2 O5, we got $32.91 over cost whereas an extra expenditure of $18.26 the returns were only $17.41 more.

Glancing at the column headed per cent gain on fertilizer investment, we find the following order, P, P K, N P and N P K. P is much higher than any of the others being over 400% in the case of lowest prices of crop and highest cost of fertilizer, and 114% in case of maximum crop value and minimum fertilizer cost. With a complete fertilizer the minimum per cent is twenty-five and the maximum one-hundred and ninety nine.

f. Conclusions of Ohio Results:

The following conclusions are reached not only from the results of the complete rotations but from the effect of the treatments on the individual crops:

1. Apply phosphoric acid to all crops-corn, oats, wheat and hay.
2. If prices of crops are good increase the application of phosphoric acid to all crops, and apply some N to timothy.

3. If more money is available, apply a small application of potash to corn—say, twenty pounds per acre. This potash may also be applied to the hay crop.

4. Any further applications of fertilizers would depend on the availability of money to use for this purpose and also on the price of crop and fertilizer. But if prices are good and money is at hand nitrogen may be added to wheat to good profit. If, however, the prices of crops are very low, this would not be justifiable.

3. Results at the Pennsylvania Station:

At this station the crops grown were corn, oats, wheat and clover in four year rotations. The results are an average of twenty-five years. Fertilizer was applied to corn and wheat, but no fertilizer was used for oats and hay. Any increase in oats and hay may be said to be due to the residual effect of the fertilizer.

a. Corn: The results (table 9) show some increase in crop value from all treatments, except nitrogen applied alone, in which case there was

Table 9. Fertilizer on Corn grown in four years rotation at the Pennsylvania Station. Average increase per A. for twenty five years and value of increase.

Lbs. per A.			Inc. Bu. per A.	Inc. Lbs. Stover per A.	Value of Inc. grain	Value of Stover	Total Value of Increase
N	P_2O_5	K_2O					
If Corn is worth 47¢ per Bu. Stover $4. per Ton.							
24	—		-1.1	- 51	-.52	-.10	-.62
	48		5.8	346	3.73	.49	3.22
		100	-1.0	346	-.47	.49	.02
24	48		9.1	352	4.28	.70	4.98
24		100	.2	355	.09	.71	.80
	48	100	11.9	846	5.59	1.69	7.28
24	48	100	8.8	830	4.14	1.66	5.80
If Corn is worth 59¢ per Bu. Stover $5. per Ton.							
24			- 1.1	- 51	-.65	-.13	-.78
	48		5.8	346	3.42	.62	4.04
		100	-1.0	346	-.59	.62	.03
24	48		9.1	352	5.37	.88	6.25
24		100	.2	355	.12	.89	1.01
	48	100	11.9	846	7.01	2.12	9.13
24	48	100	8.8	830	5.19	2.08	7.27
If Corn is worth 71¢ per Bu. Stover $6. per Ton.							
24			-1.1	-51	-.78	-.15	-.93
	48		5.8	346	4.12	.74	4.86
		100	-1.0	346	-.71	.74	.03
24	48		9.1	352	6.46	1.06	7.52
24		100	.2	355	.14	1.07	1.21
	48	100	11.9	846	8.84	2.54	11.38
24	48	100	8.8	830	6.25	2.49	8.74

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an actual decrease in grain and stover. Potash applied alone increased the stover but decreased the grain. P K gave the largest increase in crop followed by N P K , N P, P, N K. In table 10 we see that in the main the increase from the treatments was not sufficient to pay the cost of the fertilizer and harvest. Only two treatments gave a profit under any circumstances and these were the single applications of phosphoric acid and of phosphoric acid and potash combined. In two cases where the price of the crop is low we fail to figure a profit from phosphoric acid. In four cases out of nine P K gave a profit, two of which were greater than that from phosphoric acid alone. It should be stated that the increase from the use of fertilizer is much greater now than at the beginning of the experiment and this is true for all the crops at this station.

Under these conditions we would advise the use of a small application of phosphoric acid (say twenty-four pounds per acre). If the price of the crop be higher and fertilizer relatively cheap, we might apply a small amount of potash, not over ten pounds per acre.

b. Oats: Here the increase is due to the residual effect of fertilizer. We note that all treatments increased the crops save the single application of nitrogen which decreased the crop. The order of increase was N P K, P K, N P and P.

Judging from the cost of the fertilizer and from the results, I would say that a small application of phosphoric acid might pay on oats, probably twelve pounds. Phosphorus is clearly the most important single element.

c. Wheat: Table 12 shows that both nitrogen and potash when applied singly reduce the value of the wheat crop. When in combination they affect the yield very slightly. The greatest increase is from N P K, followed by N P, P K, and P_2^5

As to value of increase over cost it can hardly be said that there was any, as shown in table 13. If we take high values for crop and low prices for fertilizer we are able to figure a small profit from the use of phosphorus. In no case with phosphoric acid has the loss been very great. These results would not justify applications of fertilizer to wheat. Very

Table 11. Residual effect of fertilizers on Oats grown in four year rotation at the Pennsylvania Station. Average of twenty-five years.

Fert. app. to corn & Wheat	Inc. Bu. Grain per A	Inc. Lbs. Straw per A	Value of increase Grain	Value of increase Straw	Total val. of inc.	Cost of 7.5¢ Bu	Value over cost of Harvest.
If Oats are worth 36¢ per Bu. Straw $4. per Ton.							
N	-1.1	-13	-.40	-.03	-.43	-.08	-.35
P	3.1	162	1.12	.32	1.44½	.22	1.22
K	.6	73	.22	.15	.37	.05	.32
NP	7.1	297	2.56	.59	3.15	.53	2.62
NK	1.3	139	.47	.28	.75	.10	.65
PK	7.7	359	2.77	.72	3.49	.58	2.91
NPK	8.3	360	2.99	.72	3.71	.62	3.09
If Oats are worth 45¢ per Bu., Straw $5. per Ton							
N	-1.1	-13	-.50	-.03	-.53	-.08	-.45
P	3.1	162	1.39	.41	1.80	.22	1.58
K	.6	73	.27	.18	.45	.05	.40
NP	7.1	297	3.20	.74	3.94	.53	3.41
NK	1.3	139	.58	.35	.93	.10	.83
PK	7.7	359	3.47	.90	4.37	.58	3.79
NPK	8.3	360	3.74	.90	4.64	.62	4.02
If Oats are worth 54¢ per Bu., Straw $6. per Ton							
N	-1.1	-13	-.59	-.04	-.63	-.08	-.55
P	3.1	162	1.67	.49	2.16	.22	1.94
K	.6	73	.32	.22	.54	.05	.49
NP	7.1	297	3.83	.89	4.71	.53	4.18
NK	1.3	139	.70	.42	1.12	.10	1.02
PK	7.7	359	4.16	1.08	5.24	.58	4.66
NPK	8.3	360	4.48	1.08	5.56	.62	4.94

Table 13. Fertilizers on wheat grown in four year rotation at the Pennsylvania station. Average increase per A. for twenty five years and value of increase.

Lbs. per A.			Inc. Bu. Grain	Inc. Lbs. Straw	Value of Inc. Grain	Value of Inc. Straw	Total Value of Increase
N	P_2O_5	K_2O					
If Wheat is worth 72¢, and Straw $3. per Ton							
24			-1.0	-57	-.72	-.08	-.80
	48		3.3	242	1.66	.36	2.03
		100	1.6	111	1.15	.17	1.32
24	48		5.9	663	4.25	.99	5.24
24		100	-.1	59	-.07	.09	.02
	48	100	4.9	511	3.53	.77	4.30
24	48	100	7.5	1048	5.40	1.57	6.97
If Wheat is worth 90¢ and Straw $3.75 per ton							
24			-1100	-57	-.90	-.11	-1.01
	48		3.3	242	2.07	.45	2.52
		100	1.6	111	1.44	.21	1.65
24	48		5.9	663	5.31	1.24	6.55
24		100	-.1	59	-.09	.11	.02
	48	100	4.9	511	4.41	.96	5.37
24	48	100	7.5	1048	6.75	1.97	8.72
If Wheat is worth $1.08 per Bu. and Straw $4.50 per ton							
24			-1.0	-57	-1.08	-.13	-1.21
	48		3.3	242	2.48	.54	3.02
		100	-1.6	-111	-1.73	-.25	-1.98
24	48		5.9	663	6.37	1.49	7.86
24		100	-.1	59	-.11	.13	.02
	48	100	4.9	511	5.29	1.15	6.44
24	48	100	7.5	1048	8.10	2.36	10.46

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much reduced applications of P or N P might be justified but this is not certain.

d. Hay: The residual effect of nitrogen and potash used separately or in combination without phosphoric acid reduced the clover hay crop. (Table 14). All other applications increased the yield. The order of increase was from P K , N P K, N P, to P. This indicates that small applications of P K may be applied to clover hay but never any N.

e. Results of the Rotation:

Table fifteen includes the four crops and is an average of the results for the complete rotation. We see that single application of nitrogen or potash decrease the value of the four crops while all other treatments increased it in the following order---N P K, P K, N P, P, and N K.

Taking up the ~~various~~ value of the increase over the cost, we find that the only fertilizer bringing a profit in all cases is phosphoric acid applied singly. Phosphoric acid and potash combined gave a profit in every case except one where the price of the crop was low and the cost of fertilizer was high. In seven

Table 14. Residual effect of fertilizers on Clover Hay grown in four year rotation at the Pennsylvania Station. Average of twenty five years

Fert. applied to Corn & Wheat	Incrsd. Yield Lbs.	Value of Increase	Cost of Harvest $1.00 per Ton	Value of Inc. over cost of Harvest
If Hay is worth $9.74 per Ton				
N	-453	-2.21	-.23	-1.98
P	427	2.08	.21	1.87
K	-294	-1.43	-.15	-1.28
NP	800	3.90	.40	3.50
NK	-19	-.09	-.01	-.08
PK	1355	6.60	.68	5.92
NPK	1215	5.92	.61	5.31
If Hay is worth $12.18 per Ton				
N	-453	-2.76	-.23	-3.53
P	427	2.60	.21	3.39
K	-294	-1.79	-.15	-1.64
NP	800	4.88	.40	4.48
NK	-19	-.13	-.01	-.11
PK	1355	8.26	.68	7.58
NPK	1215	7.40	.61	6.79
If Hay is worth $14.62 per Ton				
N	-453	-3.31	-.23	-3.08
P	427	3.12	.21	2.91
K	-294	-2.15	-.15	-2.00
NP	800	5.85	.40	5.45
NK	-19	-.14	-.01	-.13
PK	1355	9.90	.68	9.22
NPK	1215	8.88	.61	8.27

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instances, the increase over cost was greater for phosphoric acid and potash than for phosphoric acid alone. The per cent gain on the fertilizer investment was always greatest from phosphoric acid applied singly. The complete fertilizer gave a profit only in three cases which were high price crops and low price fertilizer. It might be mentioned in this connection that those who use a complete fertilizer are the ones who buy it already mixedand therefore pay more for it.

f. Conclusions of Pennsylvania Station:

Our conclusions from the results at the Pennsylvania Station, influenced somewhat by the size of the application used and by the results at the North Carolina and Ohio Stations, would be about as follows:

1. Apply phosphoric acid in small amounts-10 to 30 pounds per acre to all crops of corn, oats, wheat and clover hay.
2. Apply potash 5 to 10 pounds per acre to corn and hay. If
3. If prices of wheat are good apply 5 to 10 pounds of nitrogen per acre.

This would probably cost, on the average,

about $1.50 per acre, and might be increased as the price of the crop increased or as the cost of the fertilizer decreased.

3.

Results at the North Carolina Station.

We have results for only seven years and for cotton and for corn which were planted on the same land but not in any systematic rotation. (See Bulletin Nos. 139 and 140)

a Corn: The increase in yield and value of crop are shown in Table 16. Potash and nitrogen used singly gave a decreased yield of stover and only slightly increased the yield of grain. The value of the crop was greatest from the use of complete fertilizer followed by N P , P K , P, and N K. In Table 17 we see that Nitrogen and potash applied singly ~~on~~ or in combination did not in any instance pay the cost of fertilizer and harvest. Phosphorus, then, was the most important single element, but the addition of a small amount of potash greatly increased the net value, and this treatment in all cases gave the highest net returns and also the highest per cent on the investment. N P K gave the next best returns, but the per cent on the

Table 16. Fertilizere on Corn grown on Cecil& clay loam (N.C.Sta.) Average of seven years, showing increase Bu. of grain and lbs. of stover and their value at different sale prices.

Lbs. per A.			Inc. in Bu per A.	Inc. in Lb Stov.	Value of Grain	Value of Stover	Total Value of Increase
N	P_2O_5	K_2O					
When Corn brings 47¢ per Bu. Stover $4. per Ton.							
9			.6	-73	.28	-.15	.13
	21		6.2	291	2.91	.58	3.49
		4.5	.1	-113	.05	-.23	-.18
9	21		18.8	901	8.84	1.80	10.64
9		4.5	1.5	151	.70	.30	1.00
9	21	4.5	19.1	1069	8.98	2.14	11.12
	21	4.5	16.5	1015	7.76	2.03	9.79
When Corn brings 59¢ per Bu. and Stover $5. per Ton.							
9			.6	-73	.35	-.18	.17
	21		6.2	291	3.66	.73	4.39
		4.5	.1	-113	.06	-.28	-.22
9	21		18.8	901	11.09	2.23	13.32
9		4.5	1.5	151	.88	.38	1.26
9	21	4.5	19.1	1069	11.27	2.67	15.94
	21	4.5	16.5	1035	9.74	2.59	12.33
When Corn bringe 71¢ per Bu. and Stover $6. per Ton.							
9			.6	-73	.43	-.22	.21
	21		6.2	291	4.40	.87	5.27
		4.5	.1	-113	.07	-.34	-.27
9	21		18.8	901	13.35	2.70	16.05
9		4.5	1.5	151	1.06	.45	1.51
9	21	4.5	19.1	1069	13.56	3.19	16.75
	21	4.5	16.5	1035	11.71	3.10	14.81

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investment was slightly greater from the use of N P than from N P K.

These results show a very large gain in per cent on investment from the use of P K in the combination given here. The smallest percentage was 373 ~~and~~ while the highest was 1085, representing $6.43 and $13.03 per acre respectively.

From these results P and K are the elements to be applied to corn in a combination in which the phosphoric acid is almost five times that of the potash. Further results published in Bulletin 140 show these proportions to be about the best.

b. Cotton: The results with cotton were somewhat similar to those or corn although showing some marked differences.

Nitrogen alone reduced the yield. (Table 18) All other treatments increased it in the following order: N P K, N P , P K, P, N K and K. As is shown in Table 19, the increase in these cases was more than enough to pay for the fertilizer and cost of harvest.

A fertilizer containing N K P gave in the main the greatest net gains over cost of harvest and

Table 18. Fertilizers on Cotton grown on Cecil Clay Loam (North Carolina Station) Average of seven years showing increase in pounds per A. and value of increase.

Pounds per Acre			Increase in	Value of
N	P_2O_5	K_2O	Pounds per Acre	Increase
			When Seed-Cotton is worth 3.6¢ per Pound.	
10			-35.7	-.93
	28		419.3	15.09
		10	65.0	2.34
10	28		667.4	24.03
10		10	125.0	4.50
	28	10	637.5	22.95
10	28	10	712.5	26.10
			When Seed-Cotton is worth 4.5¢ per Pound.	
10			-35.7	-1.16
	28		419.3	18.87
		10	65.0	2.93
10	28		667.4	30.03
10		10	125.0	5.63
	28	10	637.5	28.69
10	28	10	712.5	32.06
			When Seed-Cotton is worth 5.4¢ per Pound.	
10			-35.7	-1.39
	28		419.3	22.64
		10	65.0	3.51
10	28		667/4	36.05
10		10	125.0	6.75
	28	10	637.5	34.42
10	28	10	712.5	38.47

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cost of fertilizer. This, however, was very little more ~~in~~hand in a few cases not as great as P K. The greatest net gain from a complete fertilizer was $31.20 which was $1.68 more than that for P K. The extra expenditure was $2.00 then for $1.71 spent for P K we get a net gain of $29.52 and by adding N costing $2.00 we only increase our net gain $1.71. P K gave the highest per cent on investment. The single application of phosphoric acid gave the next highest per cent on the investment followed by N P, N P K, K, and N K. Under these conditions we would apply to cotton phosphoric acid and potash, and if the price of crop were good, probably a small application of nitrogen.

IV.

General Conclusions.

a. Phosphoric acid paid well on all crops except at the Pennsylvania Station where excessive amounts were applied to corn and wheat.

b. Potash added to phosphoric acid increased the yield of all crops over phosphoric acid alone. The indications are that one fifth to one third as much potash as phosphoric acid be applied to corn, hay and cotton and possibly to wheat.

c. Nitrogen seldom gave sufficient returns to justify its use, except possibly small applications for wheat, timothy and cotton under favorable circumstances.

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